



# Overview and Status of the Bioastronautics Critical Path Roadmap (BCPR)

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“Strategic Research to Enable NASA’s Exploration Missions”  
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# BCPR Objectives

- Identify and assess risks for human space exploration
- Prioritize research and technology and communicate those priorities
- Guide solicitation, selection, and development of NASA research (ground and flight) and allocation of resources
- Assess progress toward reduction and management of risks
- Define operating bands (acceptable levels of risk)

## BCPR History

- Initiated by the Johnson Space Center (JSC) Space and Life Sciences Directorate in 1997
- Expanded to include National Space Biomedical Research Institute (NSBRI) in 1998
- BCPR has guided research solicitation and selection since 2000

- *25 Intramural Scientists + 25 NSBRI leads*
- *10-20 on each team*
- *Total of 300 attended each NSBRI retreat*
- *Presented at OBPR Biennial Symposia & NSBRI Biennial Retreats*
- *On web since 2000*

## BCPR Revisions (Rev. E, 2004)

- Expanded set of Reference Missions (ISS, Moon, & Mars)
  - Previous BCPR based only on a 30-month Mars mission
- Greater representation of NASA Advanced Human Support Technology (AHST) and NASA Space Medicine programs
- Improved statements of risks and questions
  - Previous BCPR had 55 risks; Rev. E has 50 risks
  - Rev. E eliminated redundancy but added new autonomous medical care and AHST risks
  - Rev. E includes enabling research and technology questions (EQ) that are more specific and measurable



# BCPR and OBPR Program Management

- BCPR provides framework for Codes U, M and Z Bioastronautics Strategy and for Bioastronautics components of Code U Enterprise Strategy (Bioastronautics Strategy aligns with NASA Strategic Plan)
- Code UB research portfolio is tied to BCPR
- BCPR has been revised to align with new vision for space exploration
- Revised BCPR content and processes now under review by Committee on Aerospace Medicine and Medicine in Extreme Environments of the Institute of Medicine, National Academy of Sciences and National Academy of Engineering
- BCPR configuration control by Critical Path Control Panel (CPCP) (2000-2003, 2005ff)
- Bioastronautics Science Management Team (BSMT) was chartered by Codes U, M and Z to lead current revision of the BCPR (temporarily replaced CPCP)



# BCPR Disciplines & Cross-Cutting Areas

## *Human Health & Countermeasures*

- Bone loss
- Muscle alterations & atrophy
- Neurovestibular adaptation
- Cardiovascular alterations
- Immunology, infection & hematology
- Environmental effects

## *Autonomous Medical Care*

- Clinical capabilities

## *Behavioral Health & Performance*

- Psychosocial adaptation
- Sleep & circadian rhythms
- Neuropsychological
- Space human factors – cognitive capabilities

## *Radiation Health*

- Radiation effects

## *Advanced Human Support Technologies*

- Advanced life support
- Advanced environmental monitoring
- Advanced food technology
- Advanced EVA
- Space human factors – physical capabilities



# Characteristics of BCPR Reference Missions

DRM	1 Year ISS	Lunar	Mars
Crew Size	2 +	4 – 6	6
Launch Date	2005?	NET 2015-2020	NET 2025 – 2030
Mission Duration	12 months	10 – 44 days	30 months
Outbound Transit	2 days	3 – 7 days	4 – 6 months
On-Site Duration	12 months	4 – 30 days	18 months
Return Transit	2 days	3 – 7 days	4 – 6 months
Communication lag time	0+	1.3 seconds +	3 – 20 minutes +
G-Transitions (assumes <u>no</u> artificial g)	2	4	4
Hypogravity	0 g	1/6g for up to 30 days	1/3 g for up to 18 months
Internal Environment	~ 14.7 psi	TBD	TBD
EVA	0 – 4 per mission	2 – 3/week; 4 – 15/person	2 – 3/week; 180/person



# Bioastronautics Timetable (*notional*)

- 2004: Announcement of new vision for space exploration
- 2005: Countermeasure hardware requirements (Phase A)
- 2006: Initial flight experiments; countermeasure hardware design & prototype development (Phase B)
- 2007-8: First unmanned test flight of CEV
- 2010: STS to be retired, end heavy lift/return
- 2010-13: Final ground demo of countermeasures
- 2013-16: In-flight demo/validation of integrated countermeasure suite(s)
- 2015-20: Moon human landing/exploration testbed
- 2016: End ISS validation of countermeasures
- 2025-2030: First piloted Mars mission



# BCPR Processes

## Risk Identification, Assessment, and Management

- Original list of risks, research issues culled from advisory committee reports & other sources, deliberated among discipline experts
  - All BCPR risks & questions were compared with recent advisory committee reports (e.g., CSBM Strategies Report) and revisions made where necessary
- Starting in 1997 with over 100 risks, list reduced to 55 risks in 1998 and current 50 risks in 2004 by continued deliberations, eliminating redundancy, incorporating new advisory committee reports and space flight research findings
- Discipline teams assessed risks within own disciplines, prioritized own enabling research and technology questions for each risk
- Second group of experts assessed relative priority of risks across all disciplines
- Configuration Control (CPCP - Critical Path Control Panel)
  - 2000-2003: BCPR was under configuration control (currently Bioastronautics Science Management Team controls the process)
  - Will return to configuration control in 2005



# Types of BCPR Risks

- Risk: conditional probability of adverse event or system-related inefficiency
  - Human health & medical risks from exposure to hazardous conditions of space flight (e.g., microgravity, radiation, confinement)
    - Thirty-five risks classified as human health or medical
  - System performance & efficiency risks involve technologies required for providing safe & habitable environment
    - Fifteen risks classified as system performance and efficiency-related
- Different criteria employed to assess and rate risks
  - Human health & medical risks used traditional risk assessment criteria of estimated likelihood of risk occurrence & its severity of impact on crew health or performance
  - System performance & efficiency risks rating scheme based on improved efficiency
  - Both types used risk mitigation status (readiness levels)
- Overlap across the different types of risk
  - As mitigations are validated, increased efficiency is important
  - System performance & efficiency risks can have health-related effects



# Enabling Questions Categories

Human Health and Countermeasures	Risk Assessment & Acceptability
	Mechanisms and Processes
Behavioral Health & Performance	Countermeasure Strategies
	Medical Diagnosis & Treatment
Radiation Health	Prevention (selection and countermeasures)
Autonomous Medical Care	Monitoring
	Diagnosis
	Treatment
	Informatics (cross cutting)
Advanced Human Support Technology	Research Requirements/Specifications
	Design Tools
	Technologies
	Operations and Training



# Risk Mitigation Status

## Technology Readiness Level (TRL) & Countermeasures Readiness Level (CRL)

TRL Definition	TRL/CRL Score	CRL Definition	CRL category	
Basic principles observed	1	Phenomenon observed and reported Problem defined	Basic research	
Technology concept and/or application formulated	2	Hypothesis formed, preliminary studies to define parameters. Demonstrate feasibility		
Analytical and experimental critical function/proof-of-concept	3	Validated hypothesis. Understanding of scientific processes underlying problem		
Component and/or breadboard validation in lab	4	Formulation of countermeasures concept based on understanding of phenomenon	Countermeasure development	Research to prove feasibility
Component and/or breadboard in relevant environment	5	Proof of concept testing and initial demonstration of feasibility and efficacy		
System/subsystem model or prototype demonstration in relevant environment	6	Laboratory/clinical testing of potential countermeasure in subjects to demonstrate efficacy of concept		
Subsystem prototype in a space environment	7	Evaluation with human subjects in controlled laboratory simulating operational space flight environment		
System completed and flight qualified through demonstration	8	Validation with human subjects in actual operational space flight to demonstrate efficacy and operational feasibility		Countermeasure demonstration
System flight proven through mission operations	9	Countermeasure fully flight-tested and ready for implementation	Countermeasure operations	



## Defining Levels of Accepted Risk

- Tolerance limits (desirable operating bands) for human system
  - For example
    - How much bone loss (or muscle atrophy, etc.) is acceptable?
    - Units? %? Functionality?
  - Derived from available data, expert opinion and consensus
  - Decisions require selecting best mitigation options
  - Mitigate to the best level possible (risk never zero)
- Five month effort initiated by NASA Chief Medical Officer, now underway
  - Focused NASA JSC/NSBRI team to document currently accepted risk levels
  - “Acceptable” vs. “accepted” risks



# BCPR Integration

- Risks initially derived (identified, assessed) at discipline level, but risk reduction and management requires integrated approach
  - Effective and efficient risk mitigation solutions result from:
    - Collaborations across traditional disciplines
    - Coordination among intramural and extramural researchers
    - Cooperative efforts of key players – flight surgeons, astronauts, researchers, and technology developers
  - Adoption of project management tools and practices facilitates risk reduction solutions
  - Ground-based integration sites (e.g., advanced integration matrix - AIM) are essential for demonstrating & validating readiness for meeting requirements of exploration missions
    - technology components
    - human systems
- Cross cutting areas lend themselves to “projectized” approach



# BCPR Implementation, Integration, and Validation

- Projects as implementing and integrating tools
  - Projects impose discipline on the research activities and help focus on schedule and deliverables
  - Project plans force forward and integrated planning
  - Project plans reviewed (NAR) and approved to assure management concurrence
  - Project teams should include the best experts
    - Draw on NASA and non-NASA sources
  - Project teams can also help with integration (physicians, scientists, engineers, managers and astronauts)



## BCPR Refinement Schedule

- BSMT prepared materials for IOM/NAS/NAE Review, briefed JSC & HQ
- April 1
  - BSMT delivered BCPR content and processes to CAMMEE for review
  - posted revised document to website for public comment
- April 12: CAMMEE briefing on study request
- May 25-26: Risk Rating workshop
- In preparation for delivery to CAMMEE
  - Draft operating bands, accepted risk levels (SLSD)
  - Final risk assessment
  - Web tool
- October 1: Interim Report from CAMMEE
- October 1, 2005: Final Report from CAMMEE



# Academy Review

- **Study Title:** *“Assessing the Bioastronautics Critical Path Roadmap”*
- **Study Sponsors:** Code Z, Code U, Code M
- **Actionees:** Committee on Aerospace Medicine and Medicine in Extreme Environments (CAMMEE)—IoM (primary), NAS, NAE, with NRC coordinating
- **Statement of Work**
  - Independent review of BCPR content and processes with respect to clinical issues and bioastronautics research for the missions in new exploration initiative.
    - Assessment of strengths and weaknesses.
    - Identification of unique challenges.
  - Interim report in 6 months.
  - Final report in 12 – 18 months.
- **Recommended committee composition**
  - Representative experts (e.g., discipline areas, risk assessment, medical decision-making, public health, epidemiology).
  - Exclude currently funded Bioastronautics researchers.



# Academy Review (continued)

- **Statement of Work**
  - Conduct an independent review of the content and processes currently used for communication, assessment, and implementation of the BCPR with respect to clinical issues and bioastronautics research for the missions contemplated in the President's exploration initiative
    - Assessment and report of the strengths and weaknesses
    - Identification of unique challenges
  - Interim report 6 months after initiation of study
  - Final report at completion of study approximately 12 – 18 months
- **Recommended committee composition**
  - Representative experts (e.g., discipline areas, risk assessment, medical decision-making, public health, epidemiology)
  - Exclude currently funded Bioastronautics researchers



# Rating Bioastronautics Risks

- Rating is important for programmatic reasons (allocation of resources, etc.)
- Each of the 50 risks is important and needs to be addressed for human health, safety and performance during or after space flight
- The risk is determined by the likelihood of occurrence, the severity of the consequence should it occur, and the current status of mitigation



## Risk Rating Exercises

- Repeated Risk Rating exercises since 2000
- Different participants (subcommittee; steering committee; joint astronaut / space medicine / science management workshop; senior managers)
- Generally in agreement, including highest priority risks (radiation health, clinical care, human performance & fracture risk)
- Reconciling of recent (3 @ 2004) sets of ratings now in work
- The results of one of the risk rating exercises is contained in Rev. E



# Human Health Risk Assessment Criteria (examples)

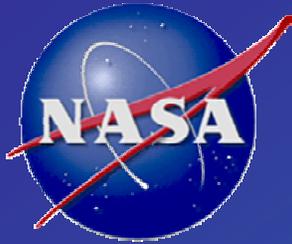
## Severity of Consequences (for example)

**Types of Consequences  
(for example)**

	Low	Moderate	High
<b>Crewmember Health In-flight</b>	No more than temporary discomfort	Short-term incapacitation or impairment	Death, significant health issue requiring mission abort or long-term incapacitation or impairment
<b>Crewmember Performance In-flight</b>	Delays of mission objectives	Loss of some mission objectives	Inability to perform critical mission functions, or total loss of mission objectives
<b>Crewmember Health Post-mission</b>	Limited increase in post-mission rehabilitation	Impairment but no long term reduced quality of life	Significant permanent disability or significantly reduced lifespan, or significant long term impairment or reduced quality of life

## Likelihoods (for example)

	Low	Moderate	High
<b>Likelihood</b>	<0.001	0.001-0.01	>0.01



# A Recent Risk Rating Exercise

- Consensus workshop participants: representatives of Astronauts, Space Medicine and Researchers
- Participants answered two questions for each BCPR risk :
  - If the US committed to sending humans to Mars today how worried would you be?
    - Scale 0 (not worried) to 10 (very worried)
  - How important is the International Space Station to reducing or eliminating the worry (for each risk)?
    - Scale 0 (not at all) to 10 (very important)
- Risk rating methodology for this exercise
  - The 3 groups independently rated 35 risks (not including 15 Advanced Human Support Technology risks)
  - Group discussion to reach consensus



# Consensus Workshop Background

- The process for evaluating & incorporating changes into BCPR is still being developed
- Position statements from the astronauts and recommendations from the flight surgeons are currently being drafted (due end of June)
- The recommendations that follow have not been fully reviewed by the workshop participants and should be considered preliminary



# Consensus Workshop Rating Analysis

- Human Health and Countermeasure Risks
  - Most microgravity physiology risks are moderate
  - ISS should be used to mitigate those risks
- Autonomous Medical Care Risks
  - Clinical risks are substantial
  - ISS important for many clinical risks
- Behavioral Health and Performance Risks
  - Critical for exploration
  - ISS only moderately useful to mitigate risks
  - Research should be done in integrated test facilities
- Radiation Risks
  - Radiation protection is essential for exploration
  - Most research should be done on Earth



# Consensus Workshop Selected Preliminary Recommendations

- “Bioastronautics Critical Path Roadmap” may not be the most appropriate title
- ISS research is important, but ground models should be emphasized
- Reword risk titles, descriptions to more accurately reflect actual risk
- Certain overarching risks should be combined
  - Need for reliable medical support hardware (including exercise equipment) for effective risk mitigation
- Further discussion of enabling questions is needed
- Incorporate integrated approach where needed
  - E.g., return to gravity rehabilitation

Other programmatic issues were also identified



# Access to BCPR Content

[http://research.hq.nasa.gov/code\\_u/bcpr/index.cfm](http://research.hq.nasa.gov/code_u/bcpr/index.cfm)  
(revised baseline document)

<http://criticalpath.jsc.nasa.gov/beta/>  
(revised searchable website—beta version!)